D. Light Towers

1. Use S.P.T. and 3" shelby tubes to sample one hole per tower.
2. Push 3" shelby tube 2.5 feet followed by the split spoon.
3. Clean out to the next 5' interval and repeat the procedure.
4. Alternate S.P.T.s and 3" shelby tubes for at least 30' below finished ground line. Take Qus (undrained shear strength), Atterberg samples, moisture samples, pocket penetrometer readings, and torvane readings.
5. In either cohesive or cohesionless soil, perform SPT test at 35’ and 40’ to complete the boring. Take Atterberg samples, moisture samples, and pocket penetrometer readings.
6. If the soil is too rocky to use the Shelby tube, split spoon on 2.5 foot intervals to achieve a depth of 30' below finished ground line and then penetrate again at 35’ and 40’ to complete the boring.
7. Amount of Rock Core.
   a. If rock is encountered within 20' of finished ground line, core 10'.
   b. If rock is more than 20' from finished ground line, core 5'.

Tower borings will need to be reported on a bridge log for spt’s and core log and a summary sheet for p-y parameters and electro-chemical parameters.

Cohesionless soil (Sand)

1. Friction Angle from Bowles 1977 using corrected Blow Count (N1)60
   (N1)60 = CnN60
   (N1)60 = N60 corrected for effective Overburden Pressure
   Cn = correction factor for Overburden Pressure (Peck et. al.1974)
2. Relative density from either DM 7.1-87 or FHWA/RD-86/102. DM 7.1 probably a better value because it accounts for effective overburden pressure.

Cohesive soils

1. Undrained Shear Strength- USS or C from Bowles 1977 using uncorrected blow count N60, preferably Qu/2.
2. Friction Angle from correlation of PI to angle of internal friction minus one standard deviation as published in Navdocks DM-7.

P-Y Curve Parameters

1. K(f) = slope (variation) of linear subgrade modulus. From Section 6.1 of the Bridge Manual or “Soil Properties (Lpile & Com624P)”
2. K(f)cyclic = for cyclic loading
3. E50 = strain at 50 % of the maximum difference in principal stresses, unitless, from Qu test and Section 6.1 of the Bridge Manual or “Soil Properties (Lpile & Com624P)”

Electro Chemical Parameters

Resistivity is a function of the chloride ion and sulfate ion content and most of the time we will not run this test. To run the test we need about half a materials sack and the sample is entered into site manager.

TABLE 4-5 EMPIRICAL VALUES FOR Φ, D_r, AND UNIT WEIGHT OF GRANULAR SOILS BASED ON CORRECTED N' (after Bowles, 1977)					
Description	Very Loose	Loose	Medium	Dense	Very Dense
Relative density D_r	0 - 0.15	0.15 - 0.35	0.35 - 0.65	0.65 - 0.85	0.85 - 1.00
Corrected standard penetration no. N'	0 to 4	4 to 10	10 to 30	30 to 50	50+
Approximate angle of internal friction ϕ *	25 - 30°	27 - 32°	30 - 35°	35 - 40°	38 - 43°
Approximate range of moist unit weight (γ) kN/m³	11.0 - 15.7	14.1 - 18.1	17.3 - 20.4	17.3 - 22.0	20.4 - 23.6

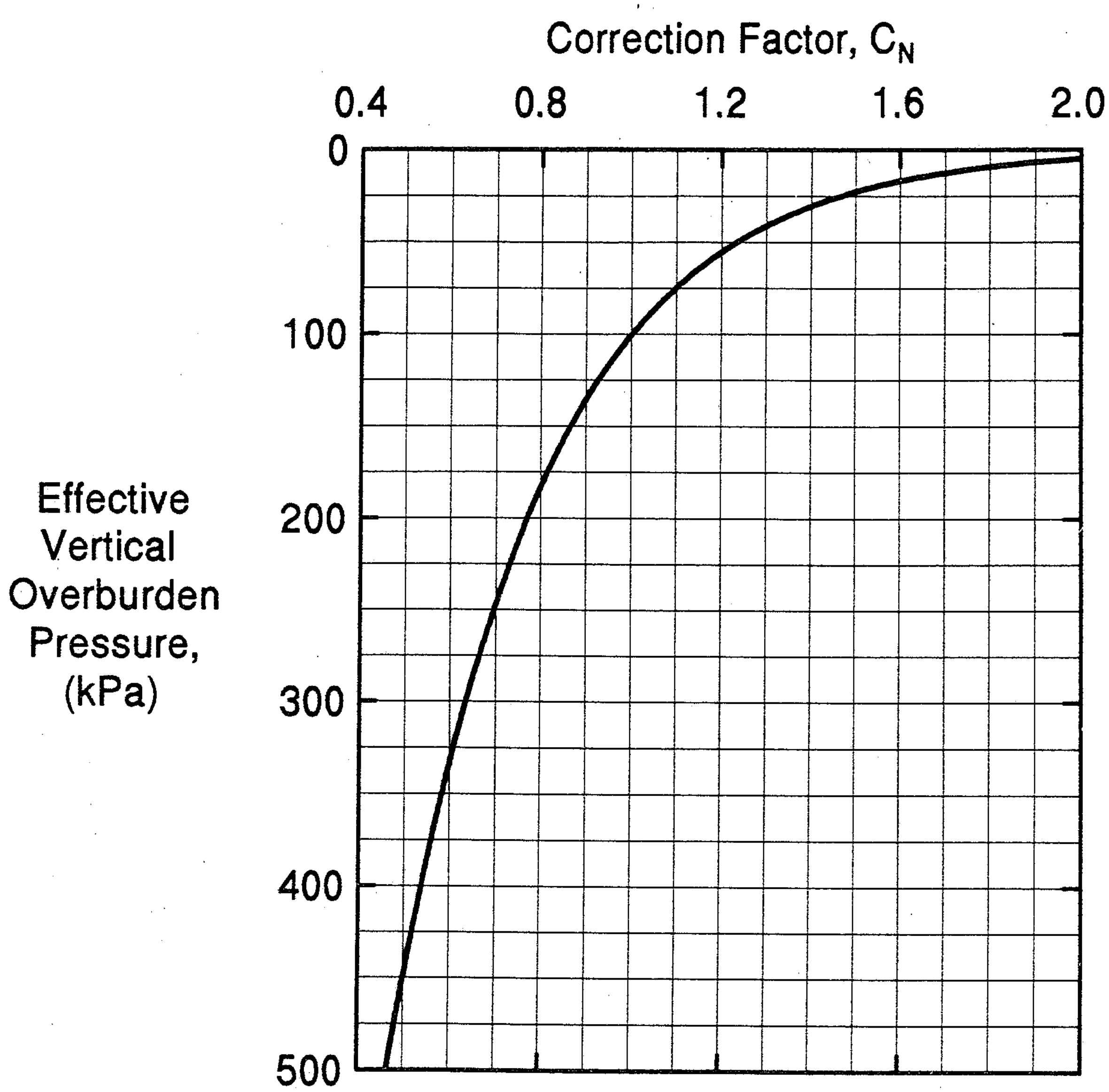
Correlations may be unreliable in soils containing gravel. See discussion in Section 9.5 of Chapter 9.

* Use larger values for granular material with 5% or less fine sand and silt.

TABLE 4-6 EMPIRICAL VALUES FOR UNCONFINED COMPRESSIVE STRENGTH (q_u) AND CONSISTENCY OF COHESIVE SOILS BASED ON UNCORRECTED N (after Bowles, 1977)						
Consistency	Very Soft	Soft	Medium	Stiff	Very Stiff	Hard
q_u, kPa	0 - 24	24 - 48	48 - 96	96 - 192	192 - 384	384+
N, Standard penetration resistance	0 - 2	2 - 4	4 - 8	8 - 16	16 - 32	32+
γ (saturated), kN/m³	15.8 - 18.8	15.8 - 18.8	17.3 - 20.4	18.8 - 22.0	18.8 - 22.0	18.8 - 22.0
The undrained shear strength is ½ of the unconfined compressive strength.						

Correlations are unreliable. Use for preliminary estimates only.

DESIGN AND CONSTRUCTION OF DRIVEN PILE FOUNDATIONS
FHWA-HI-97-03



$N' = C_N(N)$

Where: N' = corrected SPT N value.
C_N = correction factor for overburden pressure.
N = uncorrected or field SPT value.

Note: Maximum correction factor is 2.0.

ł.4 Chart for Correction of N-values in Sand for Influence of Effective Overburden Pressure (after Peck *et al.*, 1974)

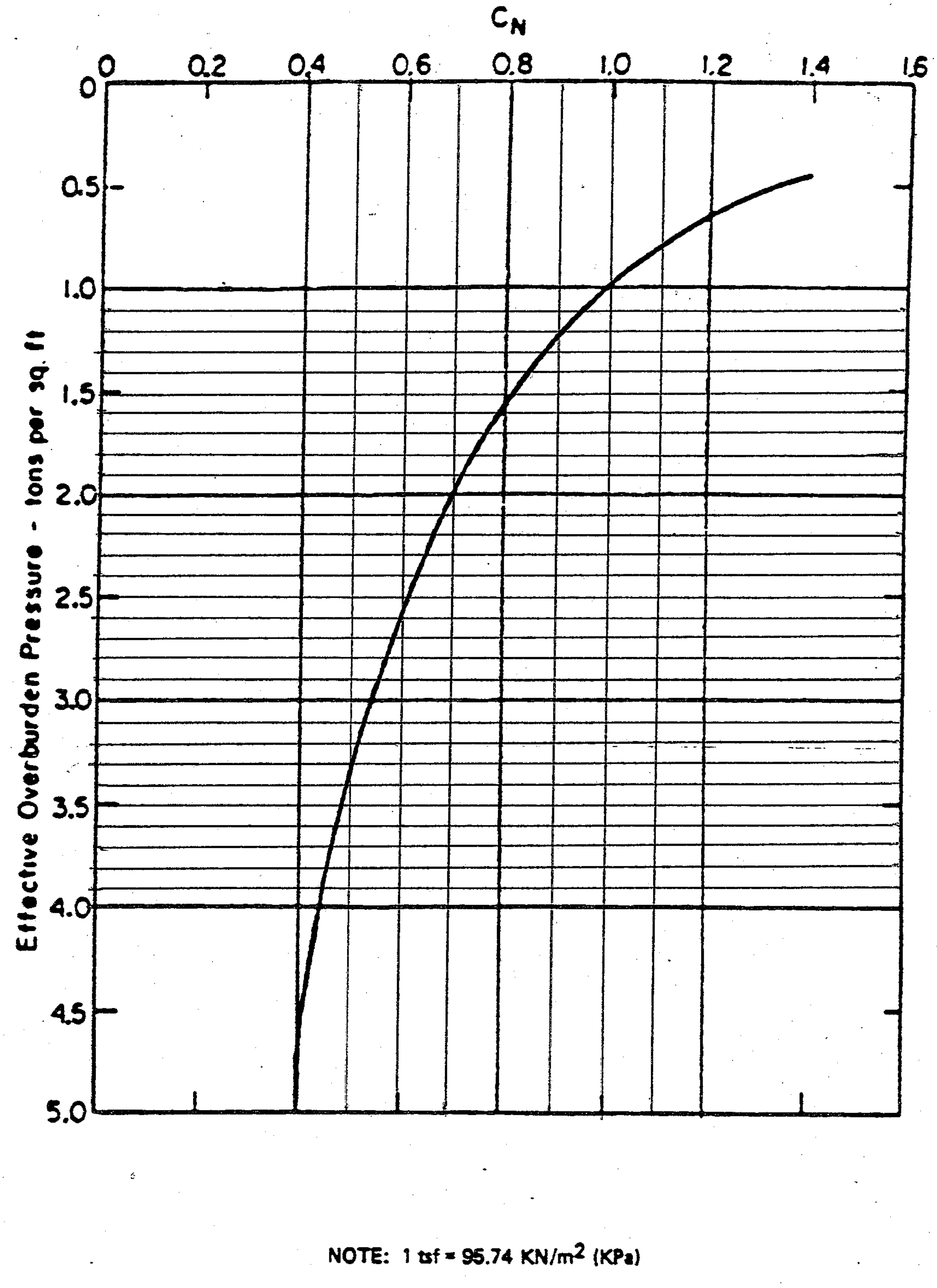


Figure 8. Relationship between C_N and effective overburden pressure.

SEISMIC DESIGN OF HIGWAY BRIDGE FOUNDATIONS - VOLUME II
JUNE 1986

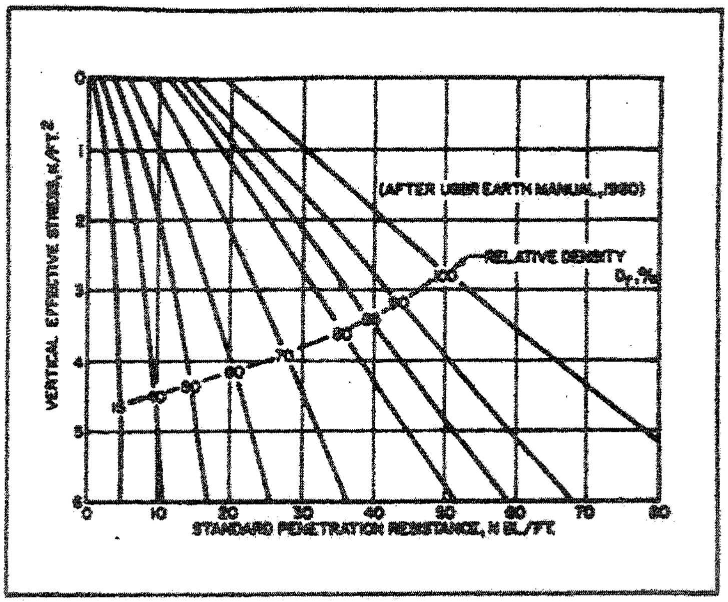


FIGURE 3
Correlations Between Relative Density and Standard Penetration Resistance in Accordance with Gibbs and Holtz

DM 7.1-87

Relative Density and Angle of Internal Friction (ϕ) for Cohesionless Soils[11,12]

Type of Soil	Resistance N (blows/ft)	Relative Density D_r	Angle of Internal Friction ϕ (Deg) Peck et al.[11]	Meyerhof[12]
Very loose sand	<4	<0.2	<29	<30
Loose sand	4–10	0.2–0.4	29–30	30–35
Medium sand	10–30	0.4–0.6	30–36	35–40
Dense sand	30–50	0.6–0.8	36–41	40–45
Very dense sand	>50	>0.8	>41	>45

FHWA/RD-86/102 PAGE 19

Undrained Shearing Strength of Cohesive Soils[13]

Penetration Resistance N (blows/ft)	Undrained Shear Strength c ($kips/ft^2$)*	Consistency
<2	<0.25	Very soft
2–4	0.25–0.50	Soft
4–8	0.50–1.00	Medium
8–15	1.00–2.00	Stiff
15–30	2.00–4.00	Very stiff
>30	>4.00	Hard

FHWA/RD-86/102 PAGE 20

Soil Properties

TABLE 6.1.2.4-2: SOIL PROPERTY CORRELATIONS
In the absence of experimentally-determined soil properties, these values may be used as rough estimates.

GRANULAR SOILS / SANDS & GRAVELS

	$(N_1)_{60}$ (blows/ft.)	ϕ (deg)	S_u (ksf)	Dr (relative density)	grain size	E (ksf)	Poisson's ratio, ν	soil type distribution	γ_{dry} (pcf)	$\gamma_{sat.}$ (pcf)	wet(below W.T.) dry(above W.T.)	K(f) * (pci)
Very Loose	0 - 5	27.00	0 - 0.5	0.10	fine	100.00	0.25	uniform	88.00	115.00	wet	10
					medium	100.00	0.15	mixed	95.00	120.00	dry	15
Loose	5 - 10	28 - 30	0.5 - 1.0	0.2 - 0.4	fine	160-240	0.25	uniform	91.00	118.00	wet	20
					medium	200-600	0.2-0.25	mixed	99.00	123.00	dry	25
Medium	10 - 20	30 - 33	1.0 - 2.0	0.4 - 0.5	fine	240-300	0.25	uniform	97.00	122.00	wet	55
					medium	600-800	0.25-0.3	mixed	104.00	127.00	dry	92
Medium Dense	20 - 35	33 - 37	2.0 - 3.5	0.5 - 0.6	fine	300-400	0.25	uniform	103.00	126.00	wet	90
					medium	800-1000	0.3-0.35	mixed	110.00	131.00	dry	158
Dense	35 - 70	37 - 44	3.5 - 7.0	0.6 - 0.9	fine	400-600	0.25	uniform	109.00	130.00	wet	125
					medium	1000-1600	0.35-0.4	mixed	116.00	135.00	dry	225
Very Dense	75.00	45.00	8.00	0.95	fine	700.00	0.25	uniform	112.00	133.00	wet	150
					medium	1700.00	0.45	mixed	119.00	138.00	dry	270

(over)

(cont.)

COHESIVE SOILS / CLAYS & SILTS

	N_{60} (blows/ft.)	$c = S_u$ (ksf)	E (ksf)	Poisson's ratio, ν	γ_{dry} (pcf)	$\gamma_{sat.}$ (pcf)	K (f) * (pci)	ε_{50} * (in./in.)
Very Soft	0 - 5	0 - 0.5	50-150	0.50 (sat.) 0.40 (unsat.)	73.00	105.00	50.00	0.02
Soft	5 - 10	0.5 - 1.0	150-300	0.50 (sat.) 0.39 (unsat.)	76.00	110.00	100.00	0.01
Medium Stiff	10 - 20	1.0 - 2.0	300-650	0.50 (sat.) 0.38 (unsat.)	86.00	116.00	500.00	0.007
Very Stiff	20 - 35	2.0 - 3.5	650-1000	0.50 (sat.) 0.37 (unsat.)	96.00	123.00	1000.00	0.005
Hard	35 - 70	3.5 - 7.0	1000-1500	0.50 (sat.) 0.36 (unsat.)	106.00	129.00	2000.00	0.004
Very Hard	75.00	7.50	1500-2000	0.50 (sat.) 0.35 (unsat.)	108.00	134.00	3000.00	0.0035

N_{60} = Standard Penetration Test blowcount, blows / ft., to 60% machine efficiency.
ϕ = angle of internal friction, for cohesionless sands and gravels, degrees
c = cohesion of cohesive clays and silts, ksf
S_u = shear strength of soil at a given normal stress, ksf.
For sands (c = 0), $S_u = p * \tan(\phi)$, where p = effective normal stress, or $S_u = N / 10$, in ksf.
For clays (ϕ=0), S_u = c, and therefore shear capacity is independent of normal stress.
For mixed soils (ϕ-c soils), $S_u = c + p * \tan(\phi)$
For clays, c can be estimated from (unconfined compression strength, Qu)/2).
E = Young's Modulus = Elastic Modulus, ksf. $E = 2*(1+\nu)*G$
G = Shear Modulus, ksf
γ = soil unit weight, pcf. $\gamma = \gamma_{dry} * (1 + w)$, where w = water content, unitless
K = f = slope (variation) of linear subgrade modulus.

W.T. = water table elevation, feet
ε_{50} = strain at 50% of the maximum difference in principal stresses, unitless
For further estimation of soil properties, see also AASHTO Div. I, Ch. 4.

* : For p-y curve analysis

SOIL PROPERTIES (LPILE & COM624P)

p-y Curve Criteria
Soil Modulus Parameter k
Soil Strain Parameter E50
E50 = Strain at 50% Stress Level of Clay

p-y Curve Criteria

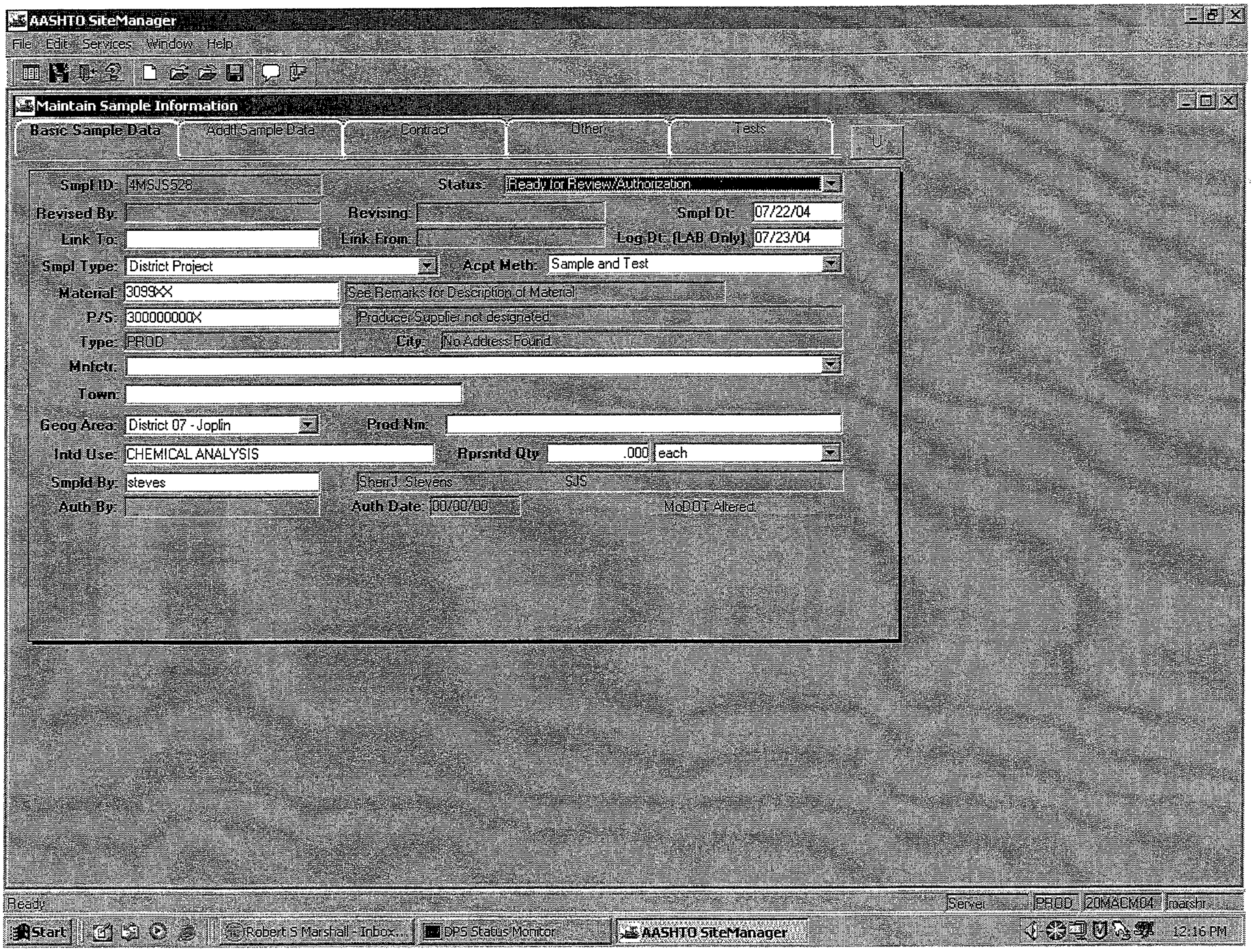
These criteria are used by LPILE1 to calculate p-y curves internally:

Option 1 – Soft Clay (Matlock, 1970)
Option 2 – Stiff Clay Below the Watertable (Reese et al., 1975)
Option 3 – Stiff Clay Above the Watertable (Reese & Welch, 1975)
Option 4 – Sand (Reese et al., 1974)

Soil Modulus Parameter k for Clays			
Average Undrained Shear Strength		**Static**	**Cyclic**
Soft Clay	c = 1.74 to 3.47 psi 250 to 500 psf 12 to 24 KPa	30 pci 8,140 KPa/m	-- --
Medium Clay	c = 3.47 to 6.94 psi 500 to 1000 psf 24 to 48 KPa	100 pci 27,150 KPa/m	-- --
Stiff Clay	c = 6.94 to 13.9 psi 1000 to 2000 psf 48 to 96 KPa	500 pci 136,000 KPa/m	200 pci 54,300 KPa/m
Very Stiff Clay	c = 13.9 to 27.8 psi 2000 to 4000 psf 96 to 192 KPa	1000 pci 271,000 KPa/m	400 pci 108,500 KPa/m
Hard Clay	c = 27.8 to 55.6 psi 4000 to 8000 psf 192 to 383 KPa	2000 pci 543,000 KPa/m	800 pci 217,000 KPa/m

Soil Modulus Parameter k for Sands			
Relative Density	**Loose**	**Medium**	**Dense**
Submerged Sand Submerged Sand	20 lb/in3 5,430 KPa/m	60 lb/in3 16,300 KPa/m	125 lb/in3 33,900 KPa/m
Sand Above WT Sand Above WT	25 lb/in3 6,790 KPa/m	90 lb/in3 24,430 KPa/m	225 lb/in3 61,000 KPa/m

Soil Strain Parameter E50		
Soft Clay	1.74 to 3.47 psi c = 250 to 500 psf 12 to 24 KPa	E50 = 0.02
Medium Clay	3.47 to 6.94 psi c = 500 to 1000 psf 24 to 48 KPa	E50 = 0.01
Stiff Clay	6.94 to 13.9 psi c = 1000 to 2000 psf 48 to 96 KPa	E50 = 0.007
Very Stiff Clay	13.9 to 27.8 psi c = 2000 to 4000 psf 96 to 192 KPa	E50 = 0.005
Hard Clay	27.8 to 55.6 psi c = 4000 to 8000 psf 192 to 383 KPa	E50 = 0.004
Limestone		E50 = 0.001


AASHTO SiteManager
File Edit Services Window Help
Maintain Sample Information
Basic Sample Data
Addl Sample Data
Contract
Other
Tests
Smpl ID: 4MSJS528
Status: Ready for Review/Authorization
Revised By:
Revising:
Smpl Dt: 07/22/04
Link To:
Link From:
Log Dt (LAB Only) 07/23/04
Smpl Type: District Project
Acpt Meth: Sample and Test
Material: 3099XX
See Remarks for Description of Material
P/S: 300000000X
Producer Supplier not designated
Type: PROD
City: No Address Found
Mnfctr:
Town:
Geog Area: District 07 - Joplin
Prod Nm:
Intd Use: CHEMICAL ANALYSIS
Rprsntd Qty .000 each
Smpld By: steves
Sherri J. Stevens SJS
Auth By:
Auth Date 00/00/00
MoDOT Altered
Ready
Server PROD 20MACM04 marshr
Start
Robert S Marshall - Inbox...
DPS Status Monitor
AASHTO SiteManager
12:16 PM

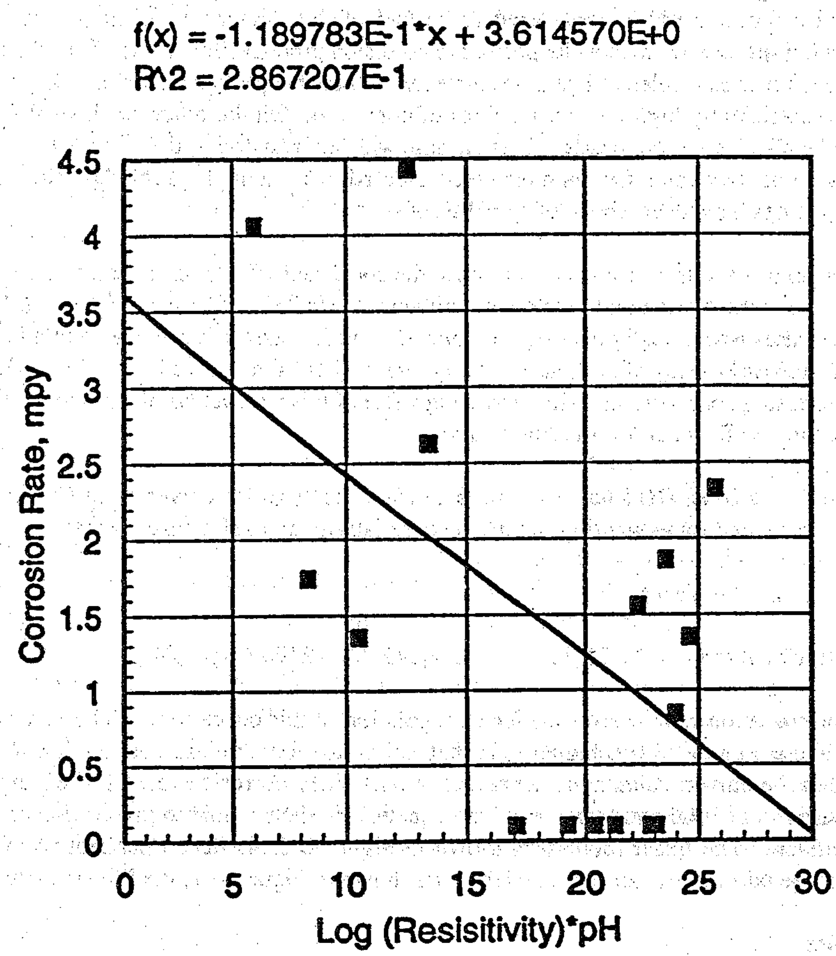


Figure D-2. Corrosion Rate as a Function of the Product of pH Times Log Resistivity for Locations on Piles Above Water Table. Data Were Taken from References Shown in Table 2.[1-5]

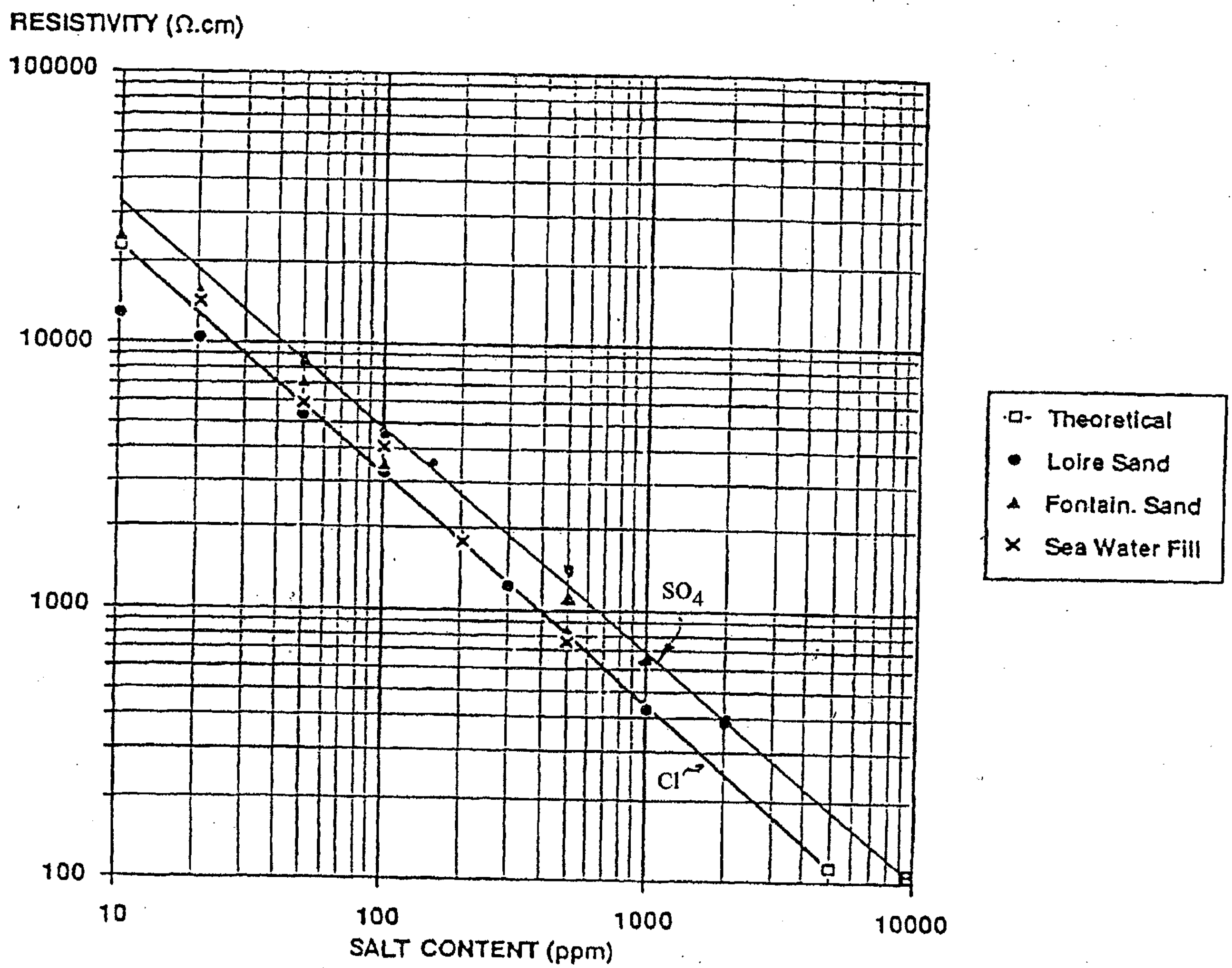


Figure 3 Resistivity vs. soluble salts

Figure 3. Resistivity vs. soluble salts.

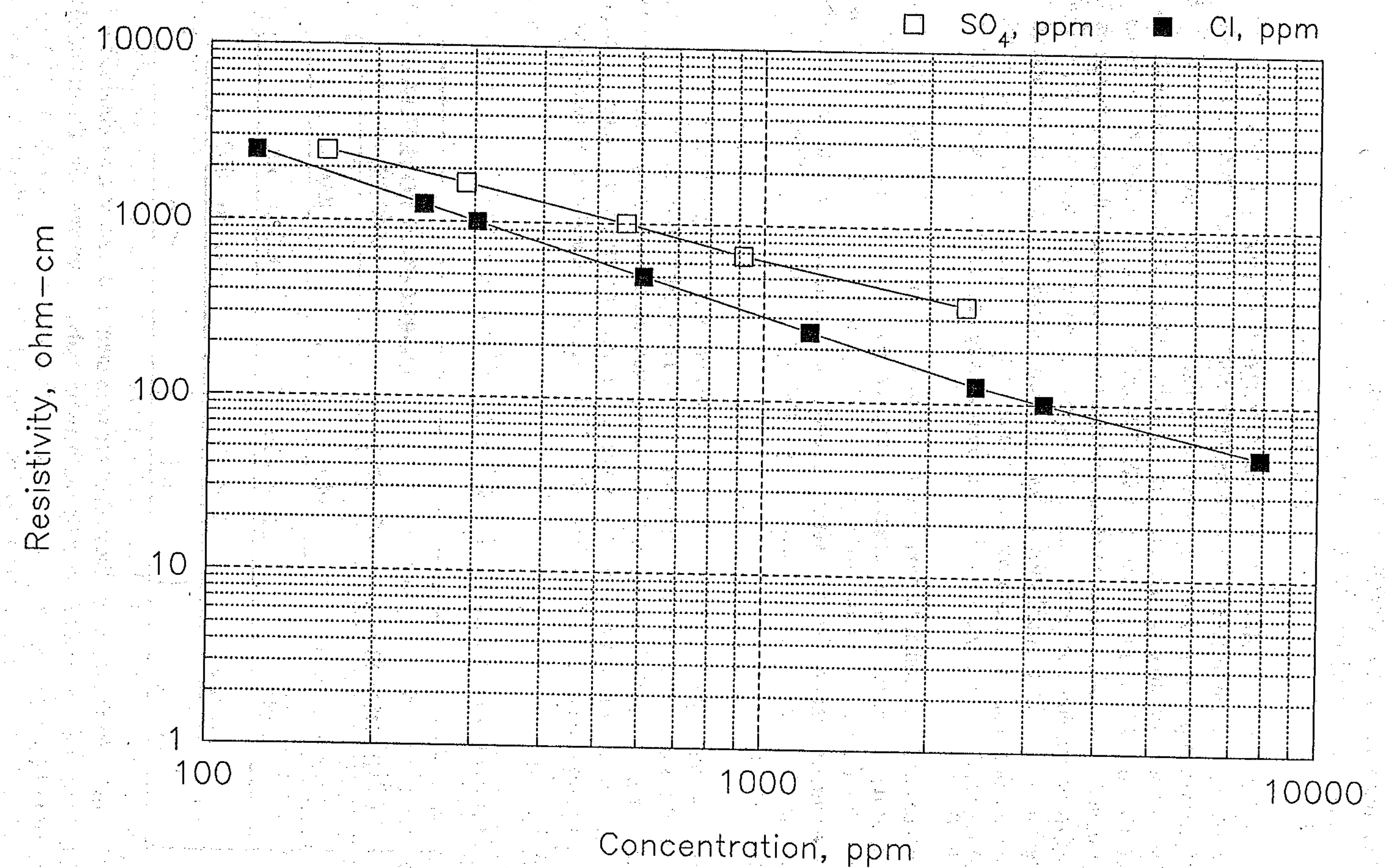


Figure D-3. Resistivity as a Function of Concentration for $CaSO_4$ and NaCl Solutions at Room Temperature.[14]

Depth	DEPTH and DESCRIPTION Elevation – 614.9’		Sample	Wn%	γmoist, pcf	γsat, pcf	LL	PI	ASTM Class.	P.P., tsf	Tv., tsf	Dr	u.s.s., pcf	Ø’°	Qu, tsf	NBlows/ft. N_{60}	(N^1_{60})	P-Y Curve Parameter $K_{(f)}$, pci	$K_{(f)}$ cyclic, pci	$\in_{50}$ in/in	Electro Chemical Classification Test Resistivity ohms-cm	ph	Sulfate Ion Concentration, ppm	Choloride Ion Concentration, ppm	Sulfides
0	0.0-5.0’	Red, tan, and gray mottled lean to fat clay, moist, very stiff.																							
			@ 1.0’	22.6	131.6	127.4	51	31	CH	9.0+	0.9+		1962		2.0										
			@ 2.5’							4.0						16		500		0.007					
5																									
	5.0-9.5’	Reddish-tan and gray sandy lean clay, with fine gravel, moist, very stiff.	@ 6.0’	16.1	136.5	135.3	40	21	CL	3.5	0.9+		4117		4.1										
			@ 7.5’													19		500		0.007					
10	9.5-15.4’	Yellowish-tan and gray shale, medium hard.																							
			@ 11.5’	22.6		127.4	46	22	CL	9.0+						100		3000		0.0035	2500	8.2	3	3	None
			@ 14.5’		140.8					9.0+			3096		3.1										
15																									
	15.4-28.0’	Dark gray silt to sand shale, hard.																							
20																									
			@ 20.7’		154.0					9.0+					27.7										
25																									
	28.0-41.0’	Light gray siltstone to mudstone, with limestone seams, thin to medium bedded, moderately hard.																							
30																									
35																									
40																									

JOB NO.: J6I1753
COUNTY: St. Charles
ROUTE: I-70
STATION: 374+48, 251.5’ RT., SB 40/61
GEN. LOC.: Pole #18

KEY:
V Water Table
U.S.S. Undrained Shearing Strength
$K_{(f)}$ cyclic For Cyclic Loading
$K_{(f)}$ Slope (Variation) of Linear Subgrade Modulus
E_{50} Strain at 50% of the Maximum Difference in Principle Stresses, Unitless

1 From FHWA/RD-86/102 Seismic Design of Highway Bridge Foundations
2 From Navdocks DM-7.1-87
3 After Bowles 1977
4 Correlation of PI to Angle of Internal Friction Minus One Standard Deviation – DM7
5 $k_{(f)}$ – From Section 6.1 of Bridge Manual or P-Y curve criteria
6 $\in_{50}$ – From Section 6.1 of Bridge Manual or P-Y curve criteria